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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Appl'n of: Peijun Ding et al.

Att'y Ref. No.: AM-1776

Appl'n No.: 08/995,108

Filed: December 19, 1997

Group Art Unit: 1745

Examiner: J. Mercado

Title: A TAILORED BARRIER LAYER WHICH PROVIDES IMPROVED COPPER INTERCONNECT ELECTROMIGRATION RESISTANCE

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APPELLANT'S BRIEF

BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

Honorable Commissioner For Patents
Washington, D.C. 20231

Sir:

This is Appellant's Brief under 37 C.F.R. §1.192 in support of the appeal of the Examiner's decision finally rejecting all of the claims in the above-identified application. A Notice of Appeal was filed on August 4, 2000. The time period for submission of an appeal brief expired October 4, 2000. A petition for a two month extension of time to respond accompanies this Appeal Brief, to extend the period for submission to December 4, 2000.

This Appeal Brief is submitted in triplicate.[1]

(1) REAL PARTY IN INTEREST

The real party in interest is Applied Materials, Inc., 3050 Bowers Avenue, Santa Clara, California 95052, by virtue of an assignment recorded by the U.S.

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1 Check Number 1001 in the Amount of $700 accompanies this Appeal Brief, to provide for the fee under 37 CFR 1.17(c) for filing of the Appeal Brief and for the fee under 37 CFR 1.17(a)(2) for an extension for response within second month. The Commissioner For Patents is authorized to charge against Deposit Account No. 50-1512 of Shirley L. Church, Esq. Los Gatos, California, any additional fees that might be necessary under 37 C.F.R. § 1.16, §1.17, or §1.18, and to credit any overpayments to the same account. A transmittal letter confirming such authorization is enclosed.

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Patent and Trademark Office on December 19, 1997, at Reel / Frame No. 8919 / 0789.

(2) RELATED APPEALS AND INTERFERENCES

There are no known related appeals or interferences.

(3) STATUS OF CLAIMS

Claims 8 - 27 are pending in the application. Claims 8 - 17 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Gelatos et al. (U.S. Patent No. 5,391,517) in view of Landers et al. (U.S. Patent No. 5,676,587). Claims 8 - 17 and 21 - 26 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Hoshino (U.S. Patent No. 4,985,750) in view of Landers. Claims 18 - 20 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Gelatos et al. in combination with Landers et al., and further in view of Ngan (U.S. Patent No. 5,707,498). Claims 18 - 20 and 27 are also rejected under 35 U.S.C. § 103(a) as being unpatentable over Hoshino in view of Landers and further in view of Ngan. None of the claims are allowed, and the rejection of each of the claims is appealed herein.

(4) STATUS OF AMENDMENTS

The Examiner, in his advisory action dated July 6, 2000, indicated that applicants' Amendment of Claim 12 in "Amendment 'B' After Final Rejection" would be entered upon filing of a Notice of Appeal and an Appeal Brief. Although the Examiner commented that he did not observe any amendment to Claim 27, there was an amendment at line 15 in which - - of said layers - - was inserted after "combination". As is apparent from Amendment "B" to claim 27, the purpose of the amendment was merely to place Claim 27 in better English syntax. The meaning of Claim 27 was not changed in applicants' opinion, and therefore applicants are presuming that this amendment to Claim 27 (as well as the amendment to Claim 12) is acceptable to the Examiner. With this in mind, the claims which are presented in the "APPENDIX" which accompanies this

Appeal Brief are the claims as amended in applicants' Amendment "B".

(5) SUMMARY OF INVENTION

In a first embodiment, the presently claimed invention pertains to a method of producing a structure which includes a barrier layer, a wetting layer, and a conductive layer overlying the wetting layer. The barrier layer is a TaN_x layer having a thickness ranging from greater than 10 Å to about 1,000Å and the wetting layer is a Ta layer having a thickness ranging from about 5Å to about 500Å. The conductive layer is deposited over the Ta layer while the substrate is at a temperature of less than about 500 °C. (Specification: Page 12, lines 4 - 7, lines 14 - 18, and lines 20 - 25, continuing at Page 13, lines 1 - 9; and Page 5, lines 22 - 24, continuing at Page 6, lines 1 - 7.)

In a second embodiment of the invention, the method described above is used to form a semiconductor interconnect structure in particular, which requires that the deposited TaN_x layer thickness range from about 50 Å to about 1,000Å and that the deposited Ta layer thickness range from about 20 Å to about 500 Å. (Abstract: Page 23, lines 26 - 28.)

In a third embodiment of the invention, the method described in the first embodiment above is used to form a contact via structure in particular, which requires that the deposited TaN_x layer range from about 10 Å to about 300 Å and that the deposited Ta layer thickness range from about 5Å to about 300 Å. (Abstract, Page 23, lines 23 - 32.)

In a fourth embodiment of the invention, at least a portion of the TaN_x barrier layer or the Ta wetting layer is deposited using a specialized sputtering technique referred to as "ion deposition sputtering". (Specification: Page 5, lines 20 - 24, continuing at Page 6, lines 1 - 9. In particular, Page 6, lines 3 - 4 and 9.) "Ion Deposition Sputtering" is a defined term, which is defined in applicants'

Specification at Page 8, lines 14 - 19. The definition requires that the initially sputtered deposition material be further ionized prior to contacting the substrate, to ensure that about 10 % or more of the sputtered emission is in the form of ions at the time the depositing material contacts the substrate surface. (This is distinguished from "traditional sputtering", where no additional ionization is carried out after sputtering, so that the amount of depositing material which is in the form of ions at the time the material contacts the substrate surface is less than 10 %, and is typically in the range of about 1 %. "Traditional Sputtering" is defined in applicants' Specification at Page 8, lines 20 - 25, continuing at Page 9, lines 1 - 3.)

In a fifth embodiment of the invention, a method of producing a copper interconnect structure is described and claimed. The copper interconnect structure comprises a combined TaN_x/Ta barrier layer/wetting layer, and a copper layer overlying the Ta wetting layer, where the Cu layer <111> crystallographic content is at least 70 % of the Cu <111> crystallographic content which can be obtained by depositing a Cu layer directly over a pure Ta layer. To obtain this high Cu layer <111> crystallographic content despite the presence of an underlying TaN_x barrier layer, the TaN_x layer is deposited to have a thickness ranging from about 50 Å to about 1,000Å, the Ta layer is deposited (over the TaN_x barrier layer) to have a thickness ranging from about 20 Å to about 500 Å, and the Cu layer is deposited (over the Ta wetting layer) using a physical vapor deposition technique. The substrate onto which the copper is deposited exhibits a temperature of less than about 500 °C. (Specification: Page 5, lines 12 - 19 and 23 -24, combined with Page 6, lines 5 - 6, and Page 7, lines 1 - 5 describe the general concept; Figure 2, shows the Cu<111> normalized peak area for a Cu layer deposited over a pure Ta layer to be 32,000; the Cu<111> normalized peak area for a Cu layer deposited over pure TaN layer to be about 2,000; and the

Cu<111> normalized peak area for a Cu/Ta/TaN structure of the invention to be about greater than about 27,000 [at least 70 %, in fact 80 %, of the Cu <111> crystallographic content obtained by depositing the Cu layer over a pure Ta layer] Figure 2 is described in more detail in the Specification at Page 14, lines 1 - 13 and at Page 15, lines 13 - 25, continuing at Page 16, lines 1 - 12. The Cu layer deposition is carried out over a substrate which is at a temperature of less than about 500 °C is described at Page 12, lines 20 - 25, for example.)

In a sixth embodiment of the invention, a method of producing a copper-comprising contact via structure is described and claimed. The contact via comprises a TaN_x/Ta/Cu structure, where the Cu layer <111> crystallographic content is at least 70 % of the Cu <111> crystallographic content which can be obtained by depositing the Cu layer over a pure Ta layer. To obtain this high Cu layer <111> crystallographic content despite the presence of a TaN_x barrier layer, the TaN_x layer is deposited to have a thickness ranging from about 10 Å to about 300Å, the Ta layer is deposited to have a thickness ranging from about 5 Å to about 300 Å, and the Cu layer is deposited using a physical vapor deposition technique where the substrate onto which the copper is deposited exhibits a temperature of less than about 500 °C. (Specification: Same general reference pages as given for the fifth embodiment pertaining to interconnects, except for the TaN_x layer and Ta layer thicknesses which are different for a contact via (as compared with an interconnect structure) and which are described at Page 5, line 24, continuing at Page 6, line 1; and at Page 6, lines 5 - 6.)

In a seventh embodiment of the invention, the method described for producing a copper-comprising contact via structure with reference to the sixth embodiment is used, but in addition, at least a portion of the TaN_x layer, or the Ta layer, or the Cu layer, or a portion of more than one of these layers is deposited using "ion-deposition sputtering". (Specification: Same general

reference pages as given for the sixth embodiment and also Page 6, lines 3 - 4 and 9.)

(6) ISSUES

The following issues exist in this appeal:

<u>ISSUE 1</u>

The rejection of Claims 8 - 17 under 35 U.S.C. § 103(a) as being unpatentable over Gelatos et al. (U.S. Patent No. 5,391,517) in view of Landers et al. (U.S. Patent No. 5,676,587).

<u>Issue 2</u>

The rejection of Claims 8 - 17 and 21 - 26 under 35 U.S.C. § 103(a) as being unpatentable over Hoshino (U.S. Patent No. 4,985,750) in view of Landers.

<u>Issue 3</u>

The rejection of Claims 18 - 20 under 35 U.S.C. § 103(a) as being unpatentable over Gelatos et al. in combination with Landers et al., and further in view of Ngan et al.(U.S. Patent No. 5,707,498).

<u>Issue 4</u>

The rejection of Claims 18 - 20 and 27 are also rejected under 35 U.S.C. § 103(a) as being unpatentable over Hoshino in view of Landers et al. and further in view of Ngan et al.

(7) GROUPING OF CLAIMS

Multiple Dependent Claims are listed as: dependent claim/independent

claim, or as: dependent claim/intermediary dependent claim.

With regard to Issues 1 - 4 presented above, applicants believe that the claims as rejected should not stand or fall together. There are several embodiments of the invention, as described above. Some of these embodiments relate to methods of forming specific structures, such as an interconnect or a contact via, which require particular and different limitations in the claims. Other embodiments require the use of a particular sputtering technique. The particular limitations required to claim the various embodiments render the subject matter of some of the claims distinguishable from the subject matter of other claims, and distinctly patentable.

With this in mind, applicants have divided the claims into groups which applicants believe are distinctly patentable, as provided below. Applicants have then addressed Issues 1 - 4 with regard to each of the claim groups provided below. As provided in 37 C.F.R. § 1.192 (c)(7), the Argument section below contains applicants' explanation of why each group of claims is believed to be separately patentable.

GROUP 1: Claims 8 - 12, 14 /8, 14/12, and 15 - 17.
GROUP 2: Claims 13, and 14 /13.
GROUP 3: Claims 18 - 20.
GROUP 4: Claims 21 - 22.
GROUP 5: Claims 23 - 26.
GROUP 6: Claim 27.

(8) ARGUMENT

Appellant's arguments in respect of each of the issues follow.

<u>ISSUE 1</u>: THE REJECTION OF CLAIMS 8 - 17 UNDER 35 U.S.C.§ 103(a) AS BEING UNPATENTABLE OVER GELATOS ET AL. IN VIEW OF LANDERS ET AL.

<u>Argument With Respect To Group 1, Claims 8 - 12, 14 / 8, 14/12 and 15 - 17</u>.

As described in applicants' Summary of the Invention at Specification Page 5, lines 12 - 19, applicants discovered that TaN_x (tantalum nitride) provides a better barrier layer than Ta (tantalum). However, copper deposited directly over TaN_x does not exhibit a sufficiently high degree of <111> crystallographic content to provide the desired copper electromigration characteristics. To provide both a barrier to the diffusion of copper into underlying layers and to enable the formation of a copper layer having the desired <111> content, it is necessary to first deposit a barrier layer of TaN_x and then deposit a wetting layer of Ta over the layer of TaN_x, followed by deposition of an overlying copper layer.

As further described at Page 6, lines 14 - 17, since the crystal orientation of the copper is sensitive to deposition temperature, it is important that the maximum temper of the copper either during deposition or subsequent annealing processes is less than about 500 °C, and preferably is about 300 °C.

Gelatos et al. discloses a three-layer "interface layer" structure which overlies the surface of a dielectric layer and comprises, from bottom to top, a first layer of titanium, a second layer of titanium nitride, and a third layer of titanium (Abstract, lines 9 - 12). Although Gelatos et al. suggests that other metals having the necessary adhesive and diffusion barrier characteristics can be employed to form the interface layer, the example provided is the use of titanium or tungsten or tantalum in place of titanium nitride as a diffusion barrier layer, and the use of chrome as the upper metal layer of the interface layer (Col. 3, lines 53 - 60). This is in contrast with applicants' teachings that tantalum does not provide an adequate barrier layer and that tantalum nitride should be used as the barrier layer while tantalum is used as an upper (wetting) layer to interface with the depositing copper.

The emphasis in Gelatos et al. is in creating a copper-titanium intermetallic layer to provide adhesion of the copper layer to the underlying

titanium nitride layer (Col. 5, lines 14 - 43). In order to create the copper-titanium intermetallic layer, Gelatos et al. uses an annealing step. The annealing step is carried out at reduced pressure and at a temperature of about 500 - 600°C (Col. 5, lines 26 - 28). As described in applicants' Amendment "A" during prosecution, copper adheres better to tantalum, so there is no need to form a copper-tantalum intermetallic layer, and no annealing step is required.

The Examiner states that ". . . Gelatos is cited to teach a substrate temperature of less than 500°C such as found within the disclosed range of 400°C to 500°C (Col. 5 line 39)." Gelatos et al. teaches that annealing may be carried out at a lower temperature of about 400°C to about 500°C only in the presence of a forming gas (N_2H_2), and that this is a less preferred alternative to simple annealing at 500 °C - 600 °C, at reduced pressure. Gelatos et al. does not suggest that a lower temperature range should be used because the electromigration characteristics of copper will be affected by the annealing temperature. Gelatos et al. teaches away from the present invention.

Landers et al. discloses a chemical mechanical planarization (polishing) method for selectively removing a layer of metallization material, such as tungsten or copper, and a liner film, such as Ti/TiN or Ta/TaN, from the surface of an oxide layer of a semiconductor wafer. At Col. 1, lines 38 - 43, Landers et al. states: "A thin liner film, generally not more than approximately 1,000 Angstroms thick is then deposited over the oxide layer. The liner generally comprises thin films of titanium (Ti) and titanium nitride (TiN) disposed over one another to form a Ti/TiN stack, or tantalum (Ta) and tantalum nitride (TaN) to form a Ta/TaN stack." However, a careful review of the Landers et al. description at Col. 1, lines 38- 43, indicates that the upper barrier layer composition which will be in contact with a tungsten or copper wiring layer is a nitrogen-containing layer which is "disposed over" the metal layer. Applicants determined that although a TaN_x layer made a good barrier layer, copper deposited over this TaN_x layer did not have the desired <111> crystallographic content and therefore had inferior electromigration resistance. The Ta layer

must be the layer in contact with the copper layer. There is nothing in Landers et al. which teaches or even suggests that a Ta layer must be in contact with the depositing metal layer, so that electromigration characteristics of the depositing metal layer will be better. As discussed in applicants' Amendment "A", the order of deposition, where the tantalum nitride layer is deposited first, and the tantalum layer is deposited thereover, is a critical feature of applicants' claimed method.

Gelatos et al. teaches that tantalum may be used as a barrier layer with an overlying layer of titanium or chrome, where the titanium or chrome is in contact with an overlying copper layer. Landers et al. also describes a barrier layer where TiN_x or TaN_x is in contact with an overlying layer of tungsten or copper. A combination of these teachings will not lead one skilled in the art to applicants' invention where a TaN_x layer is used as the barrier layer, but a Ta wetting layer is deposited over the barrier layer so that a depositing copper layer contacts the Ta wetting layer surface and a desired <111> crystallographic content is obtained in the copper layer. Whether taken alone or in combination, the disclosures of Gelatos et al. and Landers et al. neither teach nor suggest applicants' invention as claimed in Claims 8 - 12, 14 /8, 14 /12, and 15 - 17. For the reasons described above, combining the disclosure of Gelatos et al. with the disclosure of Landers et al. teaches away from the present invention. Therefore, the Board is respectfully requested to reverse the Examiner in the rejection of Claims 8 - 12, 14 /8, 14 /12, and 15 - 17 under 35 U.S.C.§ 103(a) as being unpatentable over Gelatos et al. in view of Landers et al.

<u>Argument With Respect to Group 2, Claims 13, and 14 / 13</u>

Applicants' Group 2, Claims 13, and 14/13 are distinguishable over the Gelatos et al. and Landers et al. references for the reasons described with reference to Group 1. However, and importantly, Claims 13, and 14 / 13 pertain specifically to a contact via structure, where particular TaN_x and Ta layer thicknesses are specified. These layer thicknesses are called out in Claim 13,

where the thickness of the TaN_x layer is said to range from about 10 Å to about 300 Å, and the thickness of the Ta layer is said to range from about 5 Å to about 300Å. As applicants described in their Specification at Page 5, lines 23 - 24, continuing at Page 6, lines 1 - 9, the layer thicknesses are different for an interconnect structure, compared with a contact via structure. In addition, as described in applicants' Specification at Page 13, lines 2 - 20, if the TaN_x layer is too thin, the barrier may not be adequate to prevent diffusion. (It is understood that if the TaN_x layer is too thick, the contact via size may become larger than desired.) If the Ta layer is too thin, the copper <111> crystallographic content may be inadequate to provide the desired electromigration resistance. This means that for a given device structure, having a given feature size, the TaN_x and Ta layers must be specifically designed to provide the desired barrier layer functionality and electromigration resistance. Applicants described the required layer thicknesses for a contact via based on their research, and those layer thicknesses are not described or even suggested in Gelatos et al. or Landers et al.

The disclosure in Gelatos et al. pertains to an interconnect structure, and recommends at Col. 3, lines 65 - 68, continuing at Col. 4, lines 1 - 5, that a TiN layer 18 be sputter deposited to a thickness ranging from about 300 Å to about 500 Å, and preferably about 400 Å, and that a Ti layer be sputtered over the TiN layer, where the thickness of the Ti layer ranges from about 100 Å to about 300 Å, and is preferably about 200 Å. Applicants are claiming a TaN_x layer thickness ranging from 10Å to 300Å. Gelatos et al. recommends a TiN layer thickness ranging from 300 Å to 500Å. Gelatos teaches away from applicants' claimed invention by teaching a thickness range outside that which will work in the contact via structure claimed by applicants. Landers et al. teaches a selective chemical-mechanical polishing technique for removing tungsten, copper, titanium nitride, titanium, tantalum nitride, and tantalum from a substrate surface. Although Landers does mention that the thickness of a tungsten or copper layer to be removed typically ranges from about 3,000 Å to about 11,000 Å, there is no mention of the thicknesses of layers of titanium nitride, titanium,

tantalum nitride, or tantalum which are to be removed. The only disclosure relates to the chemical-mechanical polishing removal rate for titanium nitride or titanium versus the relative removal rate of oxide, as this relates to selective polishing. Thus, nothing in Gelatos or Landers teaches or even suggests the thickness of the barrier/wetting layer structures claimed in applicants' Claims 13 and 14 / 13.

Therefore, the Board is respectfully requested to reverse the Examiner in the rejection of Claims 13 and 14 /13 under 35 U.S.C.§ 103(a) as being unpatentable over Gelatos et al. in view of Landers et al.

ISSUE 2 : THE REJECTION OF CLAIMS 8 - 17 AND 21 - 26 UNDER 35 U.S.C. § 103(a) AS BEING UNPATENTABLE OVER HOSHINO IN VIEW OF LANDERS

Argument With Respect to Group 1, Claims 8 - 12, 14 /8, 14 /12 and 15-17

Claims 8 - 17 and 21 - 26 are rejected under 35 USC § 103(a) as being unpatentable over Hoshino in view of Landers et al.

With respect to Claims 8 - 12, 14/8, 14/12, and 15 - 17, Hoshino et al. also describes a semiconductor device having a silicon substrate with a metal layer deposited over the silicon, followed by a barrier layer deposited over the metal, followed by copper deposited directly over the barrier layer. As described above with reference to Landers et al., this teaches away from applicants' invention in that it does not even suggest that the electromigration characteristics of the copper will be affected by deposition directly over the barrier layer, such as titanium nitride, tungsten nitride, zirconium nitride, and so on.

Specifically, at Col. 3, lines 28 - 66, Hoshino describes depositing a metallic layer 20 (which may be Ti, Al or platinum), followed by deposition of a barrier layer 22 (which may be selected from a laundry list including titanium nitride, tungsten, tungsten nitride, zirconium nitride, titanium carbide, tungsten carbide, tantalum, tantalum nitride, or titanium tungsten), followed by a copper metallization layer 24. Hoshino does not disclose or even

suggest that one skilled in the art should first deposit TaN_x, followed by Ta, with copper deposited over the Ta, as taught by applicants.

The Examiner has argued that a modification of the first (metal) layer in Hoshino's invention by employing its corresponding nitride would have been obvious to the skilled artisan. Apparently it is not so obvious, since all of the references cited by the Examiner which pertain to the use of Ta in combination with TaN_x show deposition of the Ta layer, followed by deposition of the TaN_x layer, followed by deposition of the copper directly over the TaN_x layer . In all of these cases, the electromigration properties of the copper will not be as good as those which will be obtained when applicants method of invention is used. Hoshino et al. addresses the problem of interdiffusion between copper and silicon, i.e. copper diffusion into adjacent layers, but does not address electromigration. Applicants' invention addresses both diffusion and electromigration; thus applicants require the deposition of the copper layer directly over a tantalum layer of a minimal thickness, where Hoshino et al. teaches that the deposition of the copper layer directly over a tantalum nitride layer is acceptable.

Further, the first (metal) layer materials recommended in the Hoshino reference did not include tantalum, but instead were limited to titanium, aluminum and platinum. In addition, Hoshino teaches that, either tantalum <u>or</u> tantalum nitride may be used as the second (barrier) layer material. Hoshino does not even suggest that tantalum is not a good barrier layer, as taught by applicants.

Whether taken alone or in combination, the disclosures of Hoshino and Landers et al. neither teach nor suggest applicants' claimed invention. In light of the above arguments, the Board is respectfully requested to reverse the Examiner in the rejection of Claims 8 - 12, 14 /8, 14 /12, and 15 - 17 under 35 USC § 103(a) as being unpatentable over Hoshino in view of Landers et al.

Argument With Respect to Group 2, Claims 13, and 14 /13

Applicants previously explained that Claims 13 and 14 /13 pertain specifically to a contact via structure, where particular TaN_x layer and Ta layer thicknesses are specified. These layer thicknesses are called out in Claim 13, where the thickness of the TaN_x layer is said to range from about 10 Å to about 300 Å, and the thickness of the Ta layer is said to range from about 5 Å to about 300Å. Applicants explained that if the TaN_x layer is too thin, the barrier may not be adequate to prevent diffusion. If the TaN_x layer is too thick, it may not be possible to fabricate a contact via of the size desired. If the Ta layer is too thin, the copper desired electromigration resistance will not be obtained. This means that for a given device structure, having a given feature size, the TaN_x and Ta layers must be specifically designed to provide the desired barrier layer performance and electromigration resistance. Applicants described the required layer thicknesses for a contact via based on their research, and as applicants explained above, those layer thicknesses are not described or even suggested in Gelatos et al. Hoshino describes barrier layers at Col. 3, lines 49 - 64. In particular, Hoshino ,teaches that the barrier layer 22 may be made of titanium nitride, tungsten, tungsten nitride, zirconium nitride, titanium carbide, tungsten carbide, tantalum, tantalum nitride, or titanium tungsten. "The film thickness of the barrier layer 22 is preferably in the range of 500 Å to 3,000Å." Again, Hoshino teaches a much thicker barrier layer that taught and claimed by applicants. There is no disclosure in Gelatos et al. or Hoshino which teaches or even suggests that a barrier layer as thin as that described and claimed by applicants would provide adequate diffusion prevention. There is no mention of electromigration resistance in either the Gelatos et al. or Hoshino references.

Whether taken alone or in combination, the disclosures of Hoshino and Landers et al. neither teach nor suggest applicants' claimed invention. In light of the above arguments, the

Board is respectfully requested to reverse the Examiner in the rejection of Claims 13 and 13 /14 under 35 USC § 103(a) as being unpatentable over Hoshino in view of Landers et al.

Argument With Respect to Group 4, Claims 21 - 22

Applicants 21 - 22 are limited to a method of producing a copper interconnect structure comprising a combined TaN_x/Ta barrier layer/wetting layer, and a copper layer overlying the Ta wetting layer, wherein the Cu <111> crystallographic content of said overlying copper layer is at least 70 % of the Cu <111> crystallographic content which can be obtained by depositing the copper layer over a pure Ta layer which is about 500 Å thick. Particular thickness limitations are placed on the TaN_x and Ta layers, and the Cu layer is deposited at a temperature of less than about 500 °C. The claims in this grouping are different from Claims 8 - 20 in that they require a particular Cu <111> crystallographic content. This difference makes these claims patentable distinct from Claims 8 - 20.

As mentioned above, the Examiner has argued that a modification of the first layer in Hoshino's invention from a metal to its corresponding nitride would have been obvious to the skilled artisan. However, all of the references cited by the Examiner which pertain to the use of Ta in combination with TaN_x show deposition of the Ta layer, followed by deposition of the TaN_x layer, followed by deposition of the copper layer. In all of these cases, the crystalline structure of the copper will not be high in <111> , and as a result the electromigration properties of the copper will not be as good as those which will be obtained when applicants method of invention is used. The Landers et al reference teaches that the copper layer is deposited directly over a layer of TiN or TaN. This teaches away from applicants' invention. However, since Landers et al. pertains to

chemical-mechanical polishing of metal layers, it is not surprising that there is no mention of Cu layer electromigration.

Whether taken alone or in combination, the disclosures of Hoshino and Landers et al. neither teach nor suggest applicants' claimed invention. In light of the above arguments, the Board is respectfully requested to reverse the Examiner in the rejection of Claims 21 and 22 under 35 USC 103(a) as being unpatentable over Hoshino in view of Landers et al.

Argument With Respect to Group 5, Claims 23 - 26

As mentioned above, Claims 21 - 22 are distinguishable from Claims 8 - 10 because they include copper crystallographic limitations. Claims 23 - 26 are distinguishable from Claims 21 - 22 in that they are limited to a method of producing a copper-comprising contact structure, which requires particular layer thicknesses for the TaN_x layer and the Ta layer. To produce the submicron-sized devices for today's semiconductor industry, it is necessary that the specified layer thicknesses be used, and there is nothing in Hoshino or in Landers et al. which suggests that the required barrier layer thicknesses be used or that these thicknesses would provide an adequate barrier layer.

In particular, as mentioned above, Hoshino ,teaches that the barrier layer 22 may be made of titanium nitride, tungsten, tungsten nitride, zirconium nitride, titanium carbide, tungsten carbide, tantalum, tantalum nitride, or titanium tungsten. Hoshino also teaches that : "The film thickness of the barrier layer 22 is preferably in the range of 500 Å to 3,000Å." Landers et al., which pertains to chemical-mechanical polishing, does not mention the thicknesses of barrier layers such as titanium, titanium nitride, tantalum or tantalum nitride which are to be removed. Since Hoshino teaches the use of barrier layers which

are much thicker than those described and claimed by applicants for use in contact vias, and since Landers does not mention any specific thickness for such barrier layers, a combination of these two references cannot lead one skilled in the art to applicants' invention.

Whether taken alone or in combination, the disclosures of Hoshino and Landers et al. neither teach nor suggest applicants' claimed invention. In light of the above arguments, the Board is respectfully requested to reverse the Examiner in the rejection of Claims 23 - 26 under 35 USC 103(a) as being unpatentable over Hoshino in view of Landers et al.

Issue 3: THE REJECTION OF CLAIMS 18 - 20 UNDER 35 U.S.C. § 103 (a) AS BEING UNPATENTABLE OVER GELATOS ET AL. IN COMBINATION WITH LANDERS ET AL, AND FURTHER IN VIEW OF NGAN ET AL.

Argument With Respect To Group 3, Claims 18 - 20

Claims 18 - 20 pertain to the use of a particular sputtering technique, "ion deposition sputtering" in the deposit of a TaN_x layer or a Ta layer. Applicants explained above that "ion-deposition sputtering" is a defined term and that it indicates a particular ionized content in material depositing on a substrate surface. Neither Gelatos et al. or Landers et al. mentions the ion content of depositing barrier layer material or a depositing wetting layer material as it is being deposited on a substrate surface.

Ngan is cited by the Examiner as showing that in the manufacture of semiconductor devices, ion-deposition sputtering is preferred over traditional sputtering in order to have uniform step coverage and filling of contact hole vias. The Ngan reference pertains to a method of avoiding contamination from an induction coil during ionized sputtering. The only

example materials mentioned are titanium and titanium nitride. One skilled in the art might decide to try to ion deposition sputter tantalum or tantalum nitride in view of the disclosure of Ngan, but it is well established in case law that "obvious to try" does not meet the requirement under 35 U.S.C. § 103 for obviousness. "The mere need for experimentation to determine parameters needed to make a device work is an application of the often rejected obvious-to-try standard and falls short of the statutory obviousness of 35 U.S.C. §103." (*Uniroyal Inc. v. Rudkin-Wiley Corp.*, 837 F.2d 1044, 5 U.S.P.Q.2d 1434 (Fed. Cir. 1988).) "An 'obvious-to-try' situation exists when a general disclosure may pique the scientist's curiosity, such that further investigation might be done as a result of the disclosure, but the disclosure itself does not contain a sufficient teaching of how to obtain the desired result or indicate that the claimed result would be obtained if certain directions were pursued." (*In re Eli Lilly & Co.*, 902 F.2d 943, 14 U.S.P.Q. 2d 1741 (Fed.Cir. 1990).) In the present instance, prior to applicants' work, there was no indication that depositing the layers specified in Claim 8 or in Claim 13 using ion-deposition sputtering would provide a structure having the advantageous properties disclosed by applicants.

Even if one skilled in the art were to combine the disclosure of Ngan with the disclosures of Gelatos et. al. and Landers et al.; the combination of the teachings would not make obvious applicants' invention, as on skilled in the art would not know that tantalum nitride makes a much better barrier layer than tantalum; that it is necessary to have tantalum (and not tantalum nitride) in contact with the overlying copper layer, nor that the use of ion-deposition sputtering during deposition of the tantalum nitride or tantalum layers would provide an advantage in step coverage without affecting another critical property of the layer deposited.

Whether taken alone or in combination, none of the references cited above teaches or suggests applicants' claimed invention. In light of the above arguments, the Board is respectfully requested to reverse the Examiner in the rejection of Claims 18 - 20 under 35 USC 103(a) as being unpatentable over Gelatos et al. in combination

with Landers et al., and further in view of Ngan.

ISSUE 4: THE REJECTION OF CLAIMS 18 - 20 AND 27 UNDER 35 U.S.C. § 103(a) AS BEING UNPATENTABLE OVER HOSHINO ET AL. IN VIEW OF LANDERS ET AL. AND FURTHER IN VIEW OF NGAN ET AL.

Argument With Respect To Group 3, Claims 18 - 20

The arguments made with respect to Issue 3 are generally applicable to Issue 4 as well. Hoshino does not address the ion content of a depositing barrier layer material or a depositing wetting layer material as it contacts a substrate surface. As mentioned above, Landers et al. does not address a sputtering technique, since it pertains to chemical-mechanical polishing. The arguments with regard to Ngan are the same as presented with regard to Issue 3.

Even if one skilled in the art were to combine the disclosure of Ngan with the disclosures of Hoshino and Landers et al.; the combination of the teachings would not make obvious applicants' invention, as on skilled in the art would not know that tantalum nitride makes a much better barrier layer than tantalum; that it is necessary to have tantalum (and not tantalum nitride) in contact with the overlying copper layer, nor that the use of ion-deposition sputtering during deposition of the tantalum nitride or tantalum layers would provide a possible advantage.

Whether taken alone or in combination, none of the references cited above teaches or suggests applicants' claimed invention. In light of the above arguments, the Board is respectfully requested to reverse the Examiner in the rejection of Claims 18 - 20 under 35 USC 103(a) as being unpatentable over Hoshino in combination with Landers et al., and further in view of Ngan.

Argument With Respect To Group 6, Claim 27

Applicants' Claim 27 pertains to a method of producing a copper-comprising contact structure having a particular Cu <111> crystallographic content, which renders Claim 27 patentably distinct from Claims 18 - 20. Like Claim 19, the barrier layer of TaN_x followed by a Ta wetting layer are each deposited to produce a layer having a thickness falling within a particular range. The thickness ranges specified are those which are necessary for submicron-sized contact vias. The copper layer deposited over the Ta wetting layer is deposited at a substrate temperature of less than about 500 °C, and at least a portion of the TaN_x layer or the Ta layer or the Cu layer, or a portion of more than one of these layers is deposited using ion-deposition sputtering. This claim is patentably distinct from any of Claims 8 - 26, because of the unique combination of claim limitations. One skilled in the art fabricating a copper-comprising contact structure will achieve a number of advantages by this particular combination of process parameters.

The arguments presented above with respect to the failure of Hoshino in combination with Landers et al, and further in view of Ngan et al. to teach or even suggest the invention as claimed in Claims 18 - 20 apply here as well. In addition, Claim 27 is further distinguished since none of these references address a particular Cu <111> crystallographic content.

Even if one skilled in the art were to combine the disclosure of Ngan with the disclosures of Hoshino and Landers et al.; the combination of the teachings would not make obvious applicants' invention, as on skilled in the art would not know that tantalum nitride makes a much better barrier layer than tantalum; that it is necessary to have tantalum (and not tantalum nitride) in contact with the overlying copper layer, that a particular Cu <111> crystallographic content is indicative of the amount of electromigration which will occur, and that the use of ion-deposition sputtering during deposition of the tantalum nitride or tantalum

layers would provide a possible advantage in step coverage while not affecting a critical characteristic of the deposited layer.

Whether taken alone or in combination, none of the references cited above teaches or suggests applicants' invention as claimed in Claim 27. In light of the above arguments, the Board is respectfully requested to reverse the Examiner in the rejection of Claim 27under 35 USC 103(a) as being unpatentable over Hoshino in combination with Landers et al., and further in view of Ngan.

Applicants believe that the claims presently pending in their application are allowable and respectfully request that the Board instruct the Examiner to permit the claims to pass to issue.

Respectfully Submitted,

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Date

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APPENDIX

The claims involved in this appeal are reproduced below.

8. A method of producing a combined barrier layer and wetting layer structure which is used in combination with a conductive layer, said method comprising the steps of:

a) depositing a first layer of TaN_x having a thickness ranging from greater than about 10 Å to about 1,000 Å;

b) depositing a second layer of Ta having a thickness ranging from about 5 Å to about 500 Å; and

c) depositing a conductive layer over a surface of said second layer of Ta, wherein the substrate temperature during said conductive layer deposition and in subsequent processing steps is less than about 500°C.

9. The method of Claim 8, wherein said conductive layer is copper.

10. The method of Claim 8, wherein said first layer of TaN_x is deposited upon a substrate having a substrate temperature ranging from about 25°C to about 500°C.

11. The method of Claim 8, wherein said second layer of Ta is deposited upon a substrate having a substrate temperature ranging from about 25°C to about 500°C.

12. The method of Claim 8, wherein said combined barrier layer and wetting layer structure is used in an interconnect structure, and wherein the thickness of said TaN_x layer

ranges from about 50 Å to about 1,000 Å and the thickness of said Ta layer ranges from about 20 Å to about 500 Å.

13. The method of Claim 8, wherein said combined barrier layer and wetting layer structure is used in a contact via structure, and wherein the thickness of said TaN_x layer ranges from about 10 Å to about 300 Å and the thickness of said Ta layer ranges from about 5 Å to about 300 Å.

14. The method of Claim 8, or Claim 12, or Claim 13, where x ranges from about 0.1 to about 1.5.

15. The method of Claim 8, wherein at least a portion of said Ta layer is deposited using a traditional, standard sputtering technique.

16. The method of Claim 12, wherein at least a portion of said Ta layer is deposited using a traditional, standard sputtering technique.

17. The method of Claim 8, wherein at least a portion of said TaN_x layer is deposited using a traditional, standard sputtering technique.

18. The method of Claim 8, wherein at least a portion of said Ta layer is deposited using ion-deposition sputtering.

19. The method of Claim 13, wherein at least a portion of said Ta layer is deposited using ion-deposition sputtering.

20. The method of Claim 8, wherein at least a portion of said TaN_x layer is deposited using ion-deposition sputtering.

21. A method of producing a copper interconnect structure comprising a combined TaN_x/Ta barrier layer and wetting layer, and an overlying copper layer, wherein the Cu <111> crystallographic content of said overlying copper layer is at least 70 % of the Cu <111> crystallographic content which can be obtained by depositing said copper layer over a pure Ta barrier layer which is about 500 Å thick, said method comprising the steps of:

a) depositing a first layer of TaN_x having a thickness ranging from greater than about 50 Å to about 1,000 Å;

b) depositing a second layer of Ta having a thickness ranging from about 5 Å to about 500 Å over the surface of said first layer of TaN_x ; and

c) depositing a third layer of copper over the surface of said second layer of Ta, wherein at least a portion of said third layer of copper is deposited using a physical vapor deposition technique, and wherein the substrate temperature at which said third layer of copper is deposited is less than about 500°C.

22. The method of Claim 21, wherein said copper interconnect structure is annealed at a temperature of less than about 500°C.

23. A method of producing a copper-comprising contact via structure comprising a combined TaN_x/Ta barrier layer and wetting layer, and an overlying copper layer, wherein the Cu < 111 > crystallographic content of said overlying copper layer is at least 70 % of the Cu <111> crystallographic content which can be obtained by depositing said copper layer over a pure Ta barrier layer which is about 300 Å thick, said method comprising the steps of:

a) depositing a first layer of TaN_x having a thickness ranging from greater than about 10 Å to about 300 Å;

b) depositing a second layer of Ta having a thickness ranging from about 5 Å to about 300 Å over the surface of said first layer of TaN_x ; and

c) depositing a third layer of copper over the surface of said second layer of Ta, wherein at least a portion of said third layer of copper is deposited using a physical vapor deposition technique, and wherein the substrate temperature at which said third layer of copper is deposited is less than about 500°C.

24. The method of Claim 23, wherein said contact-comprising structure is annealed at a temperature of less than about 500°C.

25. The method of Claim 23, wherein said copper layer is deposited at a temperature of less than about 300°C.

26. The method of Claim 25, wherein said structure is annealed at a temperature of less than about 500°C.

27. A method of producing a copper-comprising contact structure comprising a combined TaN_x/Ta barrier layer and wetting layer, and an overlying copper layer, wherein the Cu <111> crystallographic content of said overlying copper layer is at least 70 % of the Cu <111> crystallographic content which can be obtained by depositing said copper layer over a pure Ta barrier layer which is about 300 Å thick, said method comprising the steps of:

a) depositing a first layer of TaN_x having a thickness ranging from greater than about 10 Å to about 300 Å;

b) depositing a second layer of Ta having a thickness ranging from about 5 Å to about 300 Å over the surface of said first layer of TaN_x ; and

c) depositing a third layer of copper over the surface of said second layer of Ta, wherein at least a portion of said third layer of copper is deposited using a physical vapor deposition technique, and wherein the substrate temperature at which said third layer of copper is deposited is less than about 500°C,

wherein at least a portion of said first layer, or said second layer, or said third layer, or a portion of a combination of said layers, is deposited using ion-deposition sputtering..